II.4-RES-J JOINT RESERVOIR REGULATION OPERATION METHODS DESCRIPTIONS

Introduction

The Joint Reservoir Regulation Operation (RES-J) models either a single reservoir or a system of reservoirs.

It uses topological information to describe the network to be modeled. Networks may consist of reservoirs, reaches and nodes. Operation RES-J solves the network from upstream to downstream one time step at a time. Local flows to reaches and reservoirs should be generated before Operation RES-J so that they are available as network inputs.

The input to Operation RES-J consists of time series definition information, topologic information, parametric information(including RES-J methods) and rules that form the basis of a command language. The time series section establishes which time series are input to Operation RES-J and which ones will be output from Operation RES-J. The time series section also defines aliases that are used to reference time series from the RES-J components and methods. The topology section defines the connectivity of the network components. The parametric section includes parameters for network components. For example, pool elevation/storage relationships are needed for reservoirs. The parametric section also includes information for RES-J methods. Methods are used to provide modeling functionality to each of the components. Methods are internal RES-J Operations assigned to and acting upon network components, causing them to act in certain ways during simulation. Methods are analogous to the schemes/utilities that are used in the RES-SNGL Operation. They are referred to as methods to emphasize the fact that their functionality may not be the same as comparable schemes in RES-SNGL.

There are 5 categories of methods:

1. Loss methods are used to estimate changes to reservoir storage from rain and evaporation.

2. Withdrawal methods estimate discharges that are not return flow.

3. Release methods estimate reservoir discharge to the downstream component.

4. Spillway methods calculate a pseudo-implicit solution to determine any uncontrolled spill within a timestep.

5. Adjust methods adjust system states based on observations.

Complete descriptions of the RES-J methods are included later in this chapter.

A command language is used to control the execution of methods based on states of the reservoir system. The command language is in the form of rules that use a clause-action syntax. When the clause portion of a rule evaluates to TRUE, the immediate set of actions is executed. The clause consists of a conditional expression that evaluates a system state, such as a reservoir inflow, outflow or pool elevation. The action consists of RES-J methods that will be executed.

Operation RES-J Processing

Operation RES-J processing occurs in two distinct steps. The first step allocates memory for and populates a topology tree based on the parametric information stored in a RES-J control file; the second step solves the system for each time step. At its most basic level, the topology tree has a link for each network component described in the control file and pointers to the upstream and downstream components. During the parsing of the control file, conditional expressions and RES-J methods are dynamically attached to the component with which they are associated. After parsing, each topology item contains all the information needed to solve itself.

Network Solution

The process to solve the network that is described in the control file is straightforward. For each time step of the execution period, RES-J performs the following steps for each component in the topology tree moving from upstream to downstream:

1. Move through the internal list of methods assigned to the component, evaluating the conditional expression (rule) assigned to the method. If the expression evaluates to TRUE, then execute the method and continue down the list of methods.

2. Move to the next downstream component.

Following complete solution of the tree for a given time step, the tree is traversed again to update, store and reinitialize (as necessary) the state variables for each topology component. Reservoirs and Nodes will store states at the beginning of the current time step (soon to become PREVIOUS states following incrementation of the time step) and at the ending of the current time step (soon to become STARTING states following incrementation of the time step). The Reservoirs and Nodes also reinitialize the ENDING states to unknown, as they represent the values to be calculated at the end of the soon to be incremented time step. During traversal of the tree, carryover states will also be recorded for applicable components and methods, if the current time step is a carryover date.

State Variables

The manner in which state variables of the topology components are handled is an important element of the solution process. For all the components in the topology tree, initial conditions must be passed in as carryover. There is a standard set of carryover that must be specified for each component. Depending on which methods are attached to a topology item, additional information might be needed. For example, the LAGK routing method carryover consists of the initial inflow to the reach as well as a number of past inflows depending on the lag time for the reach, plus the initial outflow from the reach. Conditional expressions are evaluated using the system states from the end of the previous timestep. The ENDING states (ENDINGPOOL, etc.) begin with MISSING values, but are assigned as soon as it is possible to do so. Certain 'working state' variables are initialized at the beginning of the timestep and are used during solution of the methods. In the case of withdrawal and release, the value of the variable is calculated and recalculated as subsequent methods require. The last values are used in the mass balance for the component and even then are subject to change due to minimum constraints on the component. The POOL and STORAGE working state variables, however, are initialized using the state of the reservoir at the end of the previous timestep. These values will be updated by the pool and storage values calculated as part of any loss methods. The updated values will be used as the states of the component for reference to tables, etc. in any subsequent withdrawal and release methods. These other methods do not update the POOL and STORAGE working state variables.

Following solution of all applicable methods for a given component, the continuity equation is solved for the component. At the end of a time step, the working copy of the state variables is assigned to the set of previous state variables. Thus the states are initialized for the next timestep.

The order in which the methods are specified in the rules is important since the methods store results in the working copy of the states. In general, methods should be specified in the following order:

1. Loss methods
2. Withdrawal or Release methods
3. Spillway methods
4. Adjust methods

As mentioned above, when a loss method is computed, the working copy of the POOL and STORAGE states are overwritten by the values calculated by the loss method. If a loss method is executed before a release or withdrawal method, the computed discharge will be based on a pool elevation (and / or storage) that reflects the loss term. Release and withdrawal methods do not update the previous states with the working copy. Since the working copy of the states stores the release and withdrawal terms separately, the execution of a release method will not overwrite the results from a withdrawal method. If multiple release or withdrawal methods are executed, only the results from the last release and withdrawal methods will be retained. There is a category of methods (combo methods) that operates on other methods (SETSUM, SETMAX, SETMIN). When these methods are used, the results from each sub-method are processed sequentially, each sub-method having no knowledge of any other method or its results. After all sub-methods are processed, the results are summarized by the combo method.

<u>Evaluating Conditional Expressions</u>

To decide if a particular method is to be executed at the current time step, a conditional expression must be evaluated. A typical example of a conditional expression from the control file might be as follows:

```
[ (Saylorville.STARTINGPOOL >= 860) && \
   (Saylorville.PREVIOUSRELEASE < Node1.CRITICAL) && \
   (DATE <= 04/20) ]
```

In the preceding example, 'Saylorville.STARTINGPOOL' is a reserved string that evaluates to the pool elevation of the Saylorville reservoir at the start of the current time step (end of the previous time step). At any given time step, the usage of time-specific strings should be considered from the perspective of the current timestep: PREVIOUS* refers to the value at the beginning of the previous timestep; STARTING* refers to the value at the start of the current timestep; ENDING* refers to the value at the end of the current timestep. 'Node1.CRITICAL' is a constant that is defined by the user in the parameters section. This is a named constant that is used to facilitate changes made to the control file (i.e., the user just has to make a change in one place). The DATE keyword is used to represent the current time step that is being solved. For comparison purposes, the smallest date is 1/1 00:00:00 and the largest is 12/31 23:59. During the parsing, all the values used in a given expression (except the DATE) are tied together by their memory addresses so that lookups are not necessary during solution. This results in a much more efficient solution algorithm.

Linking Expressions and Methods

As mentioned above, the methods are attached to the topology component upon which they act. Consider the following method line in the control file:

```
::SETRELEASE Saylorville Normal1
```

This represents the SETRELEASE method with identifier Normal1 acting on reservoir Saylorville. Therefore, at run time, a SETRELEASE method is attached to the Saylorville reservoir object and is given access to the state variables of Saylorville that it needs to perform its actions. Within each topology component there is exactly one conditional expression associated with each attached method. Combining the previous two examples, for instance, would provide a complete expression-method pair:

```
[ (Saylorville.STARTINGPOOL >= 860) && (Saylorville.PREVIOUSRELEASE
< Node1.CRITICAL) && (DATE <= 04/20) ]
  ::SETRELEASE Saylorville Normal1
```

Expression-method Pairs and Solution Order

Most methods use only the state variables of the particular component item with which they are associated to arrive at a solution. This means that the entire system must be solved at a given time step before the solver can continue to the next time step. The order of components is important for methods like MAXSTAGE, BALANCE and some instances of SETWITHDRAW, which access states from other system components. System processing is accomplished by moving through the topology tree from upstream to downstream. Because the topology components are stored in memory in a tree, any method that needs to access the state variables of a topology component other than the one to which it is directly attached has access to the entire tree. This makes the solution of these methods very efficient.

Solution Process

A schematic of the solution process is shown in Figure 1.

Iterative Methods

The majority of the RES-J methods work in a linear fashion from upstream to downstream and from one time step to the next. However, there are methods (MAXSTAGE and potentially others) that require an iterative solution. With the MAXSTAGE method, the objective is to control the river stage at a downstream point without violating user-defined constraints. To solve this method, an initial release is made from the reservoir and routed downstream. The effects of this release are evaluated at the downstream control point. If a constraint is violated, the release is adjusted and the process is repeated until the objective is met, otherwise the current release is accepted. All of the iterative methods will employ a similar process. This type of method essentially suspends the action of the system-wide solver while a local solver works on a portion of the system. To accomplish this, the iterative methods instantiate their own local copy of the solver class and destroy it when the method finishes. During the secondary solution, all methods are executed in the same manner as with the primary solver, except for other iterative methods. When using MAXSTAGE, care must be taken to ensure that the methods will have access to all variables required by its expression. In other words, when the MAXSTAGE subsystem-duplicate-tree is created, only the state variables based on components in the tree are available for evaluation in an expression. For example, suppose ReservoirA has a MAXSTAGE method and ReachA, immediately downstream of ReservoirA has a LAGK method tied to an expression containing ReservoirA.STARTINGPOOL. When MAXSTAGE fires, a copy of the system beneath ReservoirA will be made. In solving the copied system, ReachA will attempt to use ReservoirA.STARTINGPOOL to determine whether to fire the LAGK method. Execution will fail as the reach will be unable to locate ReservoirA in the system copy.

General and Specific Parameters

RES-J requires two types of information: general and specific. General information includes the general parameters, time series and carryover needed to drive the model, regardless of the methods chosen to simulate the regulation plans. Specific information includes additional parameters, time series and carryover needed to execute individual methods.

The general parameters are an elevation versus storage curve and the interpolation type for using the curve. The time series are the instantaneous and mean inflow; the simulated mean outflow; and the simulated instantaneous outflow, simulated pool elevation and simulated storage contents for each reservoir. The general reservoir carryover consists of current and previous values for pool elevation, release, withdrawal and total inflow. The general node carryover consists of current and previous discharges at the node.

Section V.3.3-RES-J describes the general and specific information input requirements, including syntax and appropriate default assignments.

Method Descriptions

The following Sections describe each method. Information about the parameters, time series and carryover information is included.

Table 1 lists the method identifiers and descriptions.

Table 2 lists the symbols used in all methods. Symbols specific to an individual method are defined with that method.

Figure 1. Solution Process

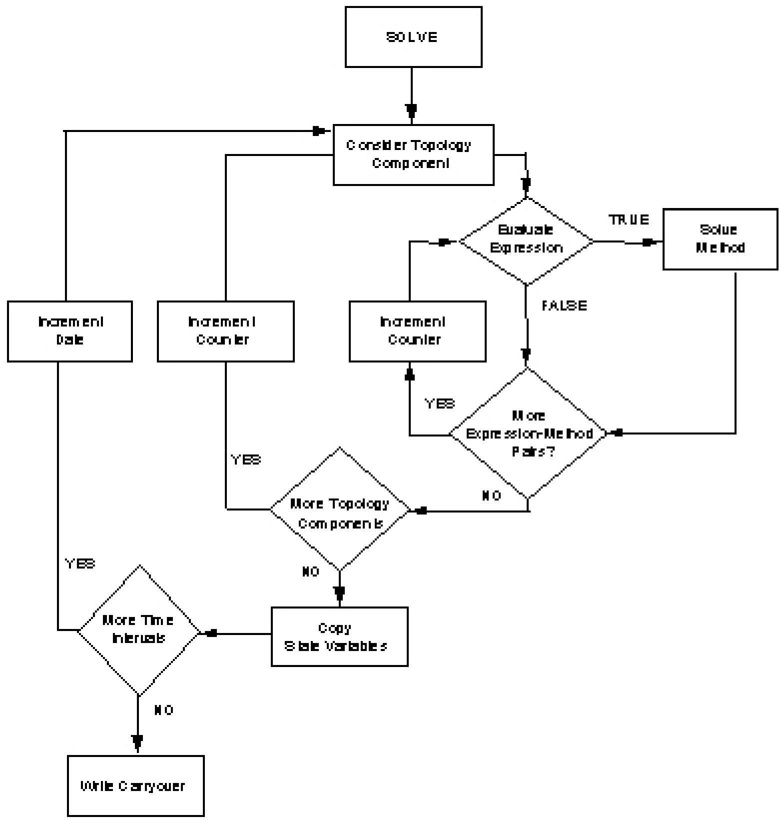

Table 1. Method Identifiers

Identifier	Description
ADJUST	Reservoir output adjustment method
BALANCE	Storage balancing for multi-reservoir systems
LAGK	Reach Lag and K routing method
MAXDECREASE	Maximum daily decrease in reservoir discharge
MAXINCREASE	Maximum daily increase in reservoir discharge
MAXSTAGE	Downstream discharge control method
RAINEVAP	Rainfall/evaporation on lake surface method
SETELEVATION	Prescribed elevation method
SETMAX	Select maximum element method
SETMIN	Select minimum element method
SETRELEASE	Prescribed release method
SETSUM	Prescribed element summing method
SETWITHDRAW	Prescribed withdrawal method
SPILLWAY	Pseudo-implicit solution of pool elevation versus spill table

Table 2. Symbols

Symbol	Description
O	Observed
S	Simulated
A	Adjusted
ND	Number of time steps since last observed discharge
B	Number of blending periods
D	Deviation between last observed discharge and simulated value (OQO-SQO)
QI	Instantaneous inflow
QI1	Instantaneous inflow at the beginning of an Operation time interval
QI2	Instantaneous inflow at the end of an Operation time interval
QO	Instantaneous outflow
QO1	Instantaneous outflow at the beginning of an Operation time interval
QO2	Instantaneous outflow at the end of an Operation time interval
QIM	Mean inflow
QOM	Mean outflow
H	Pool elevation
H1	Pool elevation at the beginning of an Operation time interval
H2	Pool elevation at the end of an Operation time interval
V	Pool storage volume
V1	Pool storage volume at the beginning of an Operation time interval
V2	Pool storage volume at the end of an Operation time interval
E	Evaporation for an Operation time interval

Symbol	Description
dt	Operation time interval

Examples

OQO represents observed instantaneous discharge
SQO represents simulated instantaneous discharge
AQO represents adjusted instantaneous discharge

Description

Method ADJUST uses observed instantaneous discharges, mean discharges and pool elevation values to adjust simulated release and pool elevation values.

The observed mean discharge time series used as input must be at the model computational time step. Output consists of adjusted simulated time series and / or adjusted carryover. Rather than placing the adjusted values in an 'adjust' time series, the ADJUST method adjusts the simulated time series or the carryover values directly.

ADJUST operates in two major modes: ADJSIM ON or OFF. If ADJSIM is OFF, only the states being saved into carryover will be adjusted based on observations. If ADJSIM is ON, ADJUST employs different adjustment procedures depending on the observed data available. The adjustment procedures for the five different possible combinations of observed data are as follows:

1. Only observed pool elevations ($Pool_{obs}$) (The water balance is not maintained.)

   A. Set the adjusted pool elevation ($Pool_{adj}$) to the observed pool elevation:

      $Pool_{adj\_t2} = Pool_{obs\_t2}$

   B. Compute the adjusted storage ($Stor_{adj}$) from the observed pool elevation and the reservoir elevation versus storage curve:

      $Stor_{adj\_t2} = f(Pool_{obs\_2})$

   C. Adjusted instantaneous discharge equals simulated instantaneous discharge"

      $Q_{adj\_t2} = Q_{sim\_t2}$

   D. Adjusted mean discharge equals simulated mean discharge:

      $Q_{adj\_mean} = Q_{sim\_mean}$

2. Only observed instantaneous discharges (Q_{obs})

   A. If the observed instantaneous discharge exists for the current computational time step (Q_{obs_t2}) set the adjusted discharge (Q_{adj_t2}) to the observed discharge:

      $Q_{adj\_t2} = Q_{obs\_t2}$
      $Diff_{t2} = Q_{obs\_t2} - Q_{sim\_t2}$
      $N = 0$

   Otherwise calculate the adjusted discharge (Q_{adj})according to:

$Q_{adj\_t2} = Q_{sim\_t2} + (Diff_{t2} * (1-(N/NBLEND))$
(If N>NBLEND, N=NBLEND)
$N = N + 1$

B. Compute the adjusted storage ($Stor_{adj\_t2}$) using the reservoir continuity equation and the adjusted discharge (Q_{adj_t2}).

C. Compute the adjusted pool elevation ($Pool_{adj}$) using the adjusted storage and the elevation versus storage curve:

$Pool_{obs\_2} = f(Stor_{adj\_t2})$

D. Compute the mean adjusted discharge (Q_{adj_mean}):

$Q_{adj\_mean} = (Q_{t1} + Q_{adj\_t2}) / 2$

3. Only observed mean discharge (Q_{obs_mean}):

A. Adjusted mean discharge (Q_{adj_mean}) equals observed mean discharge (Q_{obs_mean}):

$Q_{adj\_mean} = Q_{obs\_mean}$

B. If observed mean discharge exists for the current computational time step ($Q_{obs\_mean\_t2}$), compute the adjusted instantaneous discharge at the end of the time step (Q_{adj_t2}) using the instantaneous discharge at the end of the last time step (Q_{t1}) and the observed mean discharge (Q_{obs_mean}):

$Q_{adj\_t2} = 2 * Q_{obs\_mean} - Q_{t1}$
$Diff_{t2} =(Q_{adj\_t2} - Q_{sim\_t2})$
$N = 0$

Otherwise calculate the adjusted discharge (Q_{adj})according to:

$Q_{adj\_t2} = Q_{sim\_t2} + (Diff_{t2} * (1-(N/NBLEND))$

C. Compute the adjusted storage ($Stor_{adj\_t2}$) using the reservoir continuity equation and the adjusted release (Q_{adj_t2}).

D. Compute the adjusted pool elevation ($Pool_{adj}$) using the adjusted storage and the elevation versus storage curve:

$Pool_{obs\_2} = f(Stor_{adj\_t2})$

4. Both observed pool elevation ($Pool_{obs}$) and observed instantaneous discharge (Q_{obs}) (The water balance is not maintained.)

A. If the observed instantaneous discharge exists for the current computational time step (Q_{obs_t2}) set the adjusted discharge (Q_{adj_t2}) to the observed discharge:

$Q_{adj\_t2} = Q_{obs\_t2}$
$Diff_{t2} = Q_{obs\_t2} - Q_{sim\_t2}$
$N = 0$

Otherwise calculate the adjusted discharge (Q_{adj}) according to:

$Q_{adj\_t2} = Q_{sim\_t2} + (Diff_{t2} * (1-(N/NBLEND))$
(If N>NBLEND, N=NBLEND)
$N = N + 1$

B. Compute the mean adjusted discharge (Q_{adj_mean}):

$Q_{adj\_mean\_t2} = (Q_{adj\_t1} + Q_{adj\_t2}) / 2$

C. Set the adjusted pool elevation ($Pool_{adj}$) to the observed pool elevation ($Pool_{obs}$):

$Pool_{adj\_t2} = Pool_{obs\_t2}$

D. Compute the adjusted storage ($Stor_{adj}$) from the observed pool elevation ($Pool_{obs}$) and the reservoir elevation versus storage curve:

$Stor_{adj\_t2} = f(Pool_{obs\_t2})$

5. Both observed pool elevation ($Pool_{obs}$) and observed mean discharge (Q_{obs_mean})(The water balance is not maintained.)

A. Adjusted mean discharge (Q_{adj_mean}) equals observed mean discharge (Q_{obs_mean}):

$Q_{adj\_mean} = Q_{obs\_mean}$

B. If the observed mean discharge exists for the current computational time step ($Q_{obs\_mean\_t2}$), compute the adjusted instantaneous discharge at the end of the time step (Q_{adj_t2}) using the instantaneous discharge at the end of the last time step (Q_{t1}) and the observed mean discharge:

$Q_{adj\_t2} = 2 * Q_{obs\_mean\_t2} - Q_{t1}$
$Diff_{t2} = (Q_{adj\_t2} - Q_{sim\_t2})$
$N = 0$

Otherwise calculate the adjusted discharge (Q_{adj})according to:

$Q_{adj\_t2} = Q_{sim\_t2} + (Diff_{t2} * (1-(N/NBLEND))$
(If N>NBLEND, N=NBLEND)
$N = N + 1$

C. Set the adjusted pool elevation ($Pool_{adj}$) to the observed pool elevation ($Pool_{obs}$):

$Pool_{adj\_t2} = Pool_{obs\_t2}$

D. Compute the adjusted storage ($Stor_{adj}$) from the observed pool elevation ($Pool_{obs}$) and the reservoir elevation versus storage curve:

$$Stor_{adj\_t2} = f(Pool_{obs\_t2})$$

The ADJUST method should be the last method executed for a computational time step, thereby overwriting any discharge, storage or pool elevation previously determined by prior RES-J methods.

<u>Parameters</u>

(NBLEND)	Number of blending periods

<u>Time Series</u>

(OBSH)	Observed pool elevation time series
(OBSQO)	Observed instantaneous discharge time series
(OBSQOM)	Observed mean discharge time series (must be defined for computational time step)

<u>Carryover</u>

(N_TSTEP)	Counter used at the next time step to calculate the blend value (If blend is ongoing, this will be the # of time steps since last observed value).

II.4-RES-J-BALANCE JOINT RESERVOIR REGULATION OPERATION METHOD BALANCE

Description

For flood control, systems of reservoirs often share or balance flood control storage. Method BALANCE method does this using either remaining flood storage volume or percent of flood storage volume.

When balancing reservoir storage by remaining flood volume, users must specify the upper pool elevation or storage, for the active flood storage for each reservoir in the balance system, plus the lower pool elevation or storage for the reservoir owning the method. When balancing reservoir storage by percent of volume, users must specify both lower and upper pool elevations or storages for all reservoirs in the balance system. Regardless of the balancing mode used, values for MINRELEASE and MAXRELEASE values must be specified for the owning reservoir. An adjustment coefficient for evacuation (ACE) should be parameterized for the system. The BALANCE method is typically used within a SETMAX or SETMIN method in conjunction with other RES-J methods.

The following steps are used to balance available reservoir system storage by volume. Note that parameterized upper and lower pools are converted to corresponding storage values for solution, using the reservoir's storage / elevation table:

1. Determine the balancing storage available in each reservoir. This is the amount of currently available reservoir storage below the upper pool elevation/storage parameter.

2. Sum the amounts determined in step 1. This number represents the total available balancing storage volume in all the reservoirs.

3. Divide the amount calculated in step 2 by the number of reservoirs. This number represents the amount of balancing storage that each reservoir should have available.

4. Determine a preliminary target storage for the owning reservoir so that the remaining storage equals the quotient from step 3 above.

5. If the preliminary target storage is lower than the current storage, the target is revised by multiplying the required change in storage to reach the target by the Attenuation Constant for Evacuation (ACE). This product is then added to the original storage, resulting in a new preliminary target storage.

6. If the preliminary target storage is greater than the reservoir's upper storage, as parameterized, the target storage is reset to the upper storage.

7. If the preliminary target storage is less than the reservoir's lower storage, as parameterized, the target pool is reset to the lower pool.

8. Using a water balance approach similar to that described in the SetElevation method, the release required to arrive at the target storage is calculated.

9. The calculated release is then constrained to be within the minrelease and maxrelease values, as parameterized.

The following steps are used to balance available reservoir system storage by percent of volume. Again, note that parameterized upper and lower pools are converted to corresponding storage values for solution, using the reservoir's storage / elevation table:

1. Determine the total balancing storage specified for each reservoir. This is the amount of storage between the lower and upper elevation/storage parameters.

2. Sum the amounts determined in step 1. This number represents the total balancing storage in all reservoirs.

3. Determine the balancing storage available in each reservoir. This is the amount of reservoir storage currently below the upper pool elevation/storage parameter.

4. Sum the amounts determined in step 3. This number represents the total available balancing storage in all the reservoirs.

5. Calculate the percentage of the total balancing storage that is available by dividing the amount determined in step 4 by the amount determined in step 2.

6. Determine a preliminary target storage for the owning reservoir so that the percentage of remaining storage equals the quotient from step 3 above.

7. If the preliminary target storage is lower than the current storage, the target is revised by multiplying the required change in storage to reach the target by the Attenuation Constant for Evacuation (ACE). This product is then added to the original storage, resulting in a new preliminary target storage.

8. If the preliminary target storage is greater than the reservoir's upper storage, as parameterized, the target storage is reset to the upper storage.

9. If the preliminary target storage is less than the reservoir's lower storage, as parameterized, the target pool is reset to the lower pool.

10. Using a water balance approach similar to that described in the SetElevation method, the release required to arrive at the

target storage is calculated.

11. The calculated release is then constrained to be within the minrelease and maxrelease values, as parameterized.

Parameters

(VOLUME|PERCENT VOLUME)	Specifies whether the balancing method used is by volume or by percent of volume
(ACE|ATTENUATION_COEFFICIENT_FOR_EVACUATION)	Coefficient used to limit the extent of balancing to be accomplished during the current timestep under evacuation operations. Reduces tendency of oscillating behavior between reservoirs.
(BALRES_IDENTIFIER)	Identifies a reservoir to be used in the balancing reservoir system (there is one identifier for each reservoir defined)
(LOWERPOOL|LOWERSTORAGE)	Specifies the lower balancing pool elevation/storage level for each reservoir (this value is only needed by the reservoir owning the method if balancing by volume)
(UPPERPOOL|UPPERSTORAGE)	Specifies the upper balancing pool elevation/storage level for each reservoir
(MINRELEASE)	Specifies the minimum reservoir release for balancing (this value is only required by the owning reservoir)
(MAXRELEASE)	Specifies the maximum reservoir release for balancing (this value is only required by the owning reservoir)

Time Series

Not applicable

Carryover

Not applicable

II.4-RES-J-LAGK JOINT RESERVOIR REGULATION OPERATION METHOD LAGK

<u>Description</u>

Method LAGK is used to perform streamflow reach or internal reservoir routing.

LAGK is a common graphical routing method that combines the concepts of (1) lagging the inflow to simulate travel time in a reach and (2) attenuating the wave to simulate the storage-outflow relationship for the reach. The method solves the continuity equation using an approach similar to the Muskingum routing method (assuming that the Muskingum X parameter, loosely representing wave storage, is negligible). The governing equation for this routing technique is QI-QO=dQS/dt.

The following sections describe two options for solving LAGK for the routed outflow (QO2), given QI1 and QI2. When a LAG is applied to QI1 and QI2, the lagged values replace QI1 and QI2. Thus, the naming of the QI time series does not change for the purposes of describing the following equations.

1. Constant LAG and K

   Given user-defined constant values for LAG and K:

   A. Apply LAG to QI1 and QI2 to develop a lagged inflow hydrograph.

   B. Evaluate the following equation for QO2:

      QO2=(QI1+QI2+(2S1/dt)-QO1)/((2K/dt)+1)

   C. Solve for S2 (using S=KQO2) for the carryover storage value at the next time step.

2. Variable K

   If an outflow variable K solution scheme is specified (explicitly, in the form of tables):

   A. Apply LAG to QI1 and QI2 to develop a lagged inflow hydrograph.

   B. Develop a QO2 versus 2S2/dt+QO2 table using the supplied K versus QO table. Develop this table using the governing storage equation S=KQO.

   C. Recalling the governing equation

      2S2/dt + QO2=QI1+QI2+(2S1/dt)-QO1

      evaluate the right-hand side of this to look up the QO2 value by interpolating the table developed in step B.

D. Solve for S2 (using S2=K2QO2) for the carryover storage value for the next time step.

<u>Parameters</u>

(LAG)	Constant LAG value
(OUTFLOW)	Outflow for K versus QO table
(K)	K for K versus QO table

<u>Time Series</u>

Not applicable

<u>Carryover</u>

(COIN) N carryover inflow values where N is determined by lag and dt:

If lag = 0, 1 value is required.

If lag < time step, 2 values are required.

If (lag % time step) equals 0, lag / time step + 1 values are required ('%' represents the remainder following integer division of the first number by the second)

(OUTFLOW) Discharge from the reach. (INITIALOUTFLOW as used in LAGK parameterization).

JOINT RESERVOIR REGULATION OPERATION METHOD MAXDECREASE

Description

Method MAXDECREASE limits the decrease in release from one time step to the next.

MAXDECREASE determines the release by subtracting the maximum decrease parameter from the previous reservoir release:

$$Q_2 = Q_1 - DECREASE$$

where Q_1 is the discharge from the reservoir for the previous time step
Q_2 is the discharge prescribed for the current time step

Parameters

(DECREASE)	Maximum release decrease

Time Series

Not needed

Carryover

Not needed

II.4-RES-J-MAXINCREASE JOINT RESERVOIR REGULATION OPERATION METHOD MAXINCREASE

Description

Method MAXINCREASE limits the increase in release from one time step to the next.

MAXINCREASE determines the release by adding the maximum increase parameter and the previous reservoir release:

$$Q_2 = Q_1 - \text{INCREASE}$$

where Q_1 is the discharge from the reservoir for the previous time step
Q_2 is the discharge prescribed for the current time step

Parameters

(INCREASE) Maximum release increase

Time Series

Not needed

Carryover

Not needed

Description

Often during flooding events, reservoir outflow is restricted by a maximum permissible discharge (or stage) at a given downstream control point. Method MAXSTAGE computes a reservoir release based on this maximum allowable downstream discharge considering inflows and lag time between the reservoir and the control point.

Generally, MAXSTAGE is used as one of a number of methods defined under a combo-type method, such as SETMIN. In this fashion, MAXSTAGE will calculate an upper-limit on acceptable releases from the reservoir, but will not prescribe the release made by the reservoir except in flooding situations.

MAXSTAGE estimates an initial reservoir release and simulates the RES-J network down to the control point, which must be specified as a node. This simulation includes execution of applicable rules and methods over the number of time steps required for the release to travel to the control point (the total lag time between the reservoir and the control point). If the flow corresponding to the appropriate lag time at the control point is above (below) the maximum permissible discharge, MAXSTAGE decreases (increases) the reservoir release and repeats the process. The following steps describe the algorithm in more detail:

1. Set the primary estimated reservoir release (CURRENT_RELEASE) at the minimum allowable release (the MINRELEASE parameter as defined in the MAXSTAGE definition).

2. Solve the RES-J network for sufficient time into the future to route CURRENT_RELEASE through the network to the downstream control point. Parametric and other pertinent input data for the routing are supplied with the RES-J components between the reservoir and the control point.

3. If the stage corresponding to the routed discharge at the downstream control point is greater than the maximum allowable stage by more than an allowable criterion then MAXSTAGE will be unable to arrive at an acceptable release. A warning is printed and MINRELEASE is prescribed as the reservoir release.

4. Otherwise set boundaries on acceptable values and calculate the next release:

   A. LOWER_BOUNDARY is set to CURRENT_RELEASE.

   B. UPPER_BOUNDARY is set to twice the maximum allowable downstream discharge, as defined by the stage / discharge table.

   C. Set CURRENT_RELEASE to the midpoint of the LOWER_VARIABLE and UPPER_BOUNDARY.

5. Re-solve the RES-J network for sufficient time into the future to route CURRENT_RELEASE through the network to the downstream control point.

6. If the stage corresponding to the routed discharge at the downstream control point is greater than the maximum allowable stage by more than an allowable criterion:

   A. Set UPPER_BOUNDARY to CURRENT_RELEASE.

   B. Set CURRENT_RELEASE to the midpoint between UPPER_BOUNDARY and LOWER_BOUNDARY.

7. If the stage corresponding to the routed discharge at the downstream control point is less than the maximum allowable stage by more than an allowable criterion:

   A. Set LOWER_BOUNDARY to CURRENT_RELEASE.

   B. Set CURRENT_RELEASE to the midpoint between UPPER_BOUNDARY and LOWER_BOUNDARY.

8. If the routed reservoir release and the maximum allowable discharge are within the specified tolerance, return CURRENT_RELEASE as the prescribed reservoir release and exit.

9. If unable to exit at step 8, check if the next iteration will exceed the user-specified number of iterations. If not, return to step 5. Otherwise print a warning, return CURRENT_RELEASE as the prescribed reservoir release and exit.

Parameters

(DOWNSTREAM NODE IDENTIFIER)	Node-type component identifier (as defined in the TOPOLOGY definition section) of the control point downstream of the reservoir.
(MAXIMUM DOWNSTREAM STAGE)	Maximum permissible stage for the downstream control point (instantaneous value)
(MINIMUM REQUIRED RELEASE)	Minimum required reservoir release (instantaneous value)
(CRITERION)	A convergence criterion (represents the allowable absolute difference between the simulated downstream control point discharge and the maximum downstream discharge; when this difference is less than the criterion, the iteration stops)

(RATING CURVE)	A stage/discharge rating curve specified for the control point
(MAX ITERATIONS)	Maximum number of iterations in convergence loop

Time Series

Not applicable

Carryover

While no carry over is required for MAXSTAGE (carryover needed for the reach methods are contained within their respective implementations) there are some issues to be aware of in relation to the end of the simulation period.

Because MAXSTAGE solves into the future a certain number of time steps to route releases from the reservoir to the control point, the method will not have sufficient data available for proper solution near the end of the simulation period. For example, suppose a release takes 12 hours to travel from the reservoir to the control point, the model is running at 6 hour time step and the current time step is 6 hours from the end of simulation. To complete the routing it is necessary to solve 6 hours after the end of the simulation period. Whether running in forecast mode or in mcp3, the required inflow time series values are unavailable beyond the end of the simulation period.

To address this issue, MAXSTAGE begins solution at a time LAG hours prior to simulation end (12 hours in the example above) and uses existing time series data for the remaining time steps. Acceptable releases calculated in this fashion are returned for the original time step. This algorithm represents a reasonable use of available data, but may result in releases that would exceed the maximum allowable stage if data beyond the simulation period were available. In forecasting, the gravity of this issue is minimal, as additional simulations will likely be made prior to prescribing these releases.

II.4-RES-J-RAINEVAP JOINT RESERVOIR REGULATION OPERATION METHOD RAINEVAP

Description

Method RAINEVAP accounts for precipitation and evaporation over a lake.

Precipitation and evaporation can be supplied as a time series or daily totals in a table. If a time series is defined for either variable and has a valid value for a particular time step, RAINEVAP will use this value directly–the values represent the total over a time step. If no time series is defined or if the value is missing for a particular time step, RAINEVAP will use a value derived from a user-defined table of average daily total values. RAINEVAP will interpolate values in this table linearly, in time, to determine how much applies to a given day. As an option, users can specify a diurnal distribution of the total daily evaporation. If no distribution is specified, RAINEVAP assumes a uniform distribution over a day. When a distribution is specified, one value must be assigned for each of the computational time steps in a day. The net precipitation (PRECIP - EVAP) is applied directly to the reservoir, increasing the pool elevation if net precipitation is positive. This forces the reservoir to recalculate storage, given the new pool elevation.

Parameters

(DIST)	Daily evaporation distribution curve; first period in the curve is for the first period in the hydrologic day (if no curve is given, a uniform distribution is assumed)
(EVAP)	Daily average evaporation values

Time Series

(TS_PRECIPITATION)	Time series containing precipitation values (required)
(TS_EVAP)	Time series containing potential evaporation values

Carryover

Not needed

Description

Method SETELEVATION prescribes a reservoir release calculated to achieve a target reservoir pool elevation.

The target elevation is based on an observed value (time series) or according to user-specified DATE/ELEVATION pairs. If no time series is specified, the DATE/ELEVATION pairs are used exclusively.

SETELEVATION prescribes a reservoir release according to the following reservoir mass balance equation:

```
RELEASE = 2/DT*(D_STOR+MEAN_QIN*DT-MEAN_W*DT)-PREV_R

where DT        is the time step duration
      D_STOR    is the desired change in storage from the end of
                   the previous and current time steps (CURR_STOR-
                   TARG_STOR)
      MEAN_QIN  is the mean inflow over the time step
      MEAN_W    is the mean withdrawal over the time step
      PREV_R    is the instantaneous release at the end of the
                   previous time step
```

SETELEVATION determines a target storage by determining a target pool elevation (TARG_POOL) and querying the reservoir elevation / storage table. To determine the target pool, the following algorithm is used:

1. If an observed pool elevation time series exists and contains a non-missing value for the current solution time step, then this observed value becomes the target pool elevation.

2. Otherwise a preliminary target pool elevation is found using the date/elevation pairs list and according to the use (or absence) of the INTERPOLATE parameter.

   A. If INTERPOLATE was not defined, the preliminary target value is the release value corresponding to the date immediately prior or equal to the current time step.

   B. If INTERPOLATE was defined, the preliminary target value is linearly interpolated using Julian hour representations for the date before and after the current time step. RES-J handles year-end wrap around appropriately, as the list dates do not include year definitions.

3. If no blending parameters were defined, the target pool elevation is set equal to the preliminary target value.

4. Otherwise RES-J tests to see if starting a new blend is warranted. This can occur even if we are in the middle of blending (a partial or incomplete blend). For discussion purposes, let:

NBLEND = Number of time steps over which to blend. This is defined during SETELEVATION parameterization (value defined with BLEND or BLENDTS keyword).

N = Time step number since the current blend began. This value is reset to one at the beginning of each new blend and whenever a non-missing value is available from the input pool elevation time series.

PREL_TARG = Preliminary target value determined according to discussion above.

PREV_DATE = Date / time at the end of the previous solution time step.

CURR_DATE = Date / time at the end of the current solution time step.

POOL = Reservoir pool elevation at the beginning of the current solution time step.

A new table blend may begin if BLEND is defined, INTERPOLATE is not set and:

A. CURR_DATE is equal to a date used in the DATE/ELEVATION pairs list.

B. PREV_DATE and CURR_DATE straddle a date used in the DATE/ELEVATION pairs list.

A new time series blend may begin if BLENDTS is defined and:

A. A non-missing value exists in the release time series for PREV_DATE but the time series value is missing for CURR_DATE.

B. The time series blend is incomplete (N as initialized by a time series blend is less than or equal to NBLEND as based on the BLENDTS value) and at least one of the new table blend conditions A and B occur.

Note that if the times series continues to miss values beyond what is required to complete the time series blend (N > NBLEND), time series blending is suspended until a non-missing value is found. Any other blending which might be necessary will be performed under the rules and parameters of table blending.

5. If a blending sequence is active then,
   TARG_POOL = (PREL_TARG - POOL) / (NBLEND - N + 1)

6. Otherwise the target pool elevation is set equal to the preliminary target value.

Because RES-J operates uses instantaneous values, some oscillatory behavior may need to be dampened. This is accomplished by adjusting the prescribed release so as to enable a 'soft landing' at the target pool elevation at the end of the next time step. The prescribed release becomes the average of 1) the release determined according to the algorithm described above (which would arrive at the target pool elevation at the end of this time step) and 2) the release that would have been required to reach the target elevation for the current time step had we entered the time step at the target elevation for the previous time step. Note that if no oscillatory behavior is pending, the values of '1' and '2' will be equal (within some acceptable range of precision). This occurs if two successive target elevations are equal (independent of whether prescribed by a time series or the date/elevation pairs).

Parameters

(DATE ELEVATION)	List of dates (e.g., 01/01, 02/01) followed by a list of corresponding pool elevations
(BLEND)	Number of time steps over which to blend table values
(BLENDTS)	Number of blending time steps over which to blend time series values into the table values
(NORMAL|INTERPOLATE)	Specifies how elevations are determined for computational time steps that do not fall on dates explicitly defined in the (DATE ELEVATION) list

Time Series

(TS ELEVATION)	Time series containing elevation values

Carryover

(N)	Time step number since the current table blending sequence began.
(NTS)	Time step number since the current time series blending sequence began. This also corresponds to the time step number since the last non-missing value in the observed pool elevation time series.

II.4-RES-J-SETMAX JOINT RESERVOIR REGULATION OPERATION METHOD SETMAX

Description

Method SETMAX selects the results from a list of previously computed methods defined within the SETMAX parametric input.

SETMAX allows users to select the maximum discharge computed from several methods of a specific type (e.g., release or withdrawal). Multiple layers of SETMAX, SETMIN and SETSUM methods can be defined.

Parameters

(METHODS)	List of methods and identifiers that define the list of previously computed methods from which a maximum value is taken. Methods that may be used within SETMAX include BALANCE, MAXDECREASE, MAXINCREASE, MAXSTAGE, SETELEVATION, SETMAX, SETMIN, SETRELEASE, SETSUM and SETWITHDRAW. Release and withdrawal methods cannot be compared in a SETMAX method.

Time Series

Not needed

Carryover

Not needed

II.4-RES-J-SETMIN JOINT RESERVOIR REGULATION OPERATION METHOD SETMIN

Description

Method SETMIN selects the results from a list of previously computed methods defined within the SETMIN parametric input.

SETMIN allows users to select the minimum discharge computed from several methods of a specific type (e.g., release or withdrawal). Multiple layers of SETMAX, SETMIN and SETSUM methods can be defined.

Parameters

(METHODS)	List of methods and identifiers that define the list of previously computed methods from which a minimum value is taken. Methods that may be used within SETMIN include BALANCE, MAXDECREASE, MAXINCREASE, MAXSTAGE, SETELEVATION, SETMAX, SETMIN, SETRELEASE, SETSUM and SETWITHDRAW. Release and withdrawal methods cannot be compared in a SETMIN method.

Time Series

Not needed

Carryover

Not needed

II.4-RES-J-SETRELEASE JOINT RESERVOIR REGULATION OPERATION METHOD SETRELEASE

Description

Method SETRELEASE prescribes a reservoir release according to a user-specified table of releases (based on dates and pool elevations) or, if available, a time series of release values.

Release table behavior can be modified by specifying three types of interpolation and using blending algorithms. If no time series is specified, the table release values are used exclusively.

SETRELEASE prescribes a reservoir release according to the following algorithm. Use of the release table is also described below.

1. If an observed release time series exists and contains a non-missing value for the current solution time step, then the observed release is prescribed. Any variables tracking previous blending sequences are reinitialized.

2. Otherwise an initial target release is drawn from the release table.

   The pool elevation state at the beginning of the current time step determines which column(s) of the table is (are) used.

   A. If reservoir pool is less than the smallest elevation in the release table, the column corresponding to the smallest elevation is used. This condition should be avoided by more fully defining the release table. It is recommended that releases be specified for pool elevations at least as small as the minimum pool elevation for which the SETRELEASE method will be active–generally equal to the value of MINIMUMPOOL as defined in reservoir parameterization.

   B. If reservoir pool is greater than or equal to the largest elevation in the release table, the column corresponding to the largest elevation is used. This condition should also be avoided by expanding the release table well beyond the largest expected reservoir pool elevation.

   C. Otherwise the column corresponding to the largest elevation which is smaller than or equal to the reservoir pool will be used.

   The target value is then calculated according to the use (or absence) of the INTERPOLATE parameter.

   A. If INTERPOLATE was not defined, the target value is the release value corresponding to the date immediately prior or equal to the current time step.

B. If INTERPOLATE TIME was defined, the target value is linearly interpolated within the column using Julian hour representations for the date before and after the current time step. RES-J handles year-end wrap around appropriately, as release table dates do not include year definitions.

C. If INTERPOLATE ELEV was defined, a low-end target value is found as if no interpolation was defined. Using the release table column corresponding to the elevation just larger than the reservoir pool, a high-end target value is found in a similar fashion. The target value is then calculated by linear interpolation between the low-end and high-end values according to their respective pool elevations and the reservoir pool state.

D. If INTERPOLATE ALL was defined, a low-end target value is found as if INTERPOLATE TIME was defined. Using the release table column corresponding to the elevation just larger than the reservoir pool, a high-end target value is found in a similar fashion. The target value is then calculated by linear interpolation between the low-end and high-end values according to the associated pool elevations and the reservoir pool state.

3. If no blending parameters were defined, the prescribed release is set equal to the target value.

4. Otherwise RES-J tests to see if starting a new blend sequence is warranted. This can occur even if we are in the middle of blending (a partial or incomplete blend). For discussion purposes, let:

NBLEND	=	Number of time steps over which to blend. This is defined during SETRELEASE parameterization (value defined with BLEND or BLENDTS keyword).
N	=	Time step number since the current blend began. This value is reset to one at the beginning of each new blend and whenever a non-missing value is available from the input release time series.
TARGET	=	Target value determined according to discussion above.
PREV_R	=	Release prescribed at the end of last time step. This could be a non-missing value from a time series, a release determined from the release table or the last release prescribed as part of blending.
PREV_DATE	=	Date / time at the end of the previous solution time step.
CURR_DATE	=	Date / time at the end of the current solution time step.
PREV_POOL	=	Reservoir pool elevation at the beginning of the previous solution time step.
POOL	=	Reservoir pool elevation at the beginning of

the current solution time step.

Blending may be of two types: 1) blending across values in the release table when different columns and / or rows in the table are used at this time step as compared to the last time step (table blending) and 2) blending from a non-missing input release time series value to a value in the release table (time series blending).

A new table blending sequence may begin if BLEND is defined and:

A. CURR_DATE is equal to a date used in defining the release table and neither INTERPOLATE TIME nor INTERPOLATE ALL is set.

B. PREV_DATE and CURR_DATE straddle a date used in defining the release table and neither INTERPOLATE TIME nor INTERPOLATE ALL is set.

C. The column in the release table corresponding to the largest elevation which is smaller than or equal to PREV_POOL is different from the respective column for POOL and neither INTERPOLATE ELEV nor INTERPOLATE ALL is set.

Table blending is intended to smooth the transition from one table-prescribed release to another. Therefore, use of 'INTERPOLATE' may nullify 'BLEND' functionality. For example, if a change in pool elevation causes a different column to be used from one time step to the next, blending should occur. If however, 'INTERPOLATE ELEV' or 'INTERPOLATE ALL' has been defined, blending would be nullified as the transition across the elevation point would have already been smoothed by interpolation.

A new time series blending sequence may begin if BLENDTS is defined and:

A. A non-missing value exists in the release time series for PREV_DATE but the time series value is missing for CURR_DATE.

B. The time series blend is incomplete (N as initialized by a time series blend is less than or equal to NBLEND as based on BLENDTS value) and any of the new table blend conditions A, B or C, as described above, occur.

Note that if the time series continues to miss values beyond what is required to complete the time series blend (N > NBLEND), time series blending is suspended until a non-missing value is found in the input release time series. Any other blending which might be necessary will be performed under the rules and parameters of table blending.

5. If a blending sequence is active then,

RELEASE = PREV_R + (TARGET - PREV_R) / (NBLEND - N + 1)

6. Otherwise the prescribed release is the target value.

Parameters

(CURR_DATE)	Required - date / time at the end of the current solution time step; used with the date/pool elevation/release table and to test for initiation of new blending sequences.
(PREV_DATE)	Required - date / time at the end of the previous solution time step; used with the date/pool elevation/release table and to test for initiation of new blending sequences.
(POOL)	Required - pool elevation at the beginning of the current solution time step; used with the date/pool elevation/release table and to test for initiation of new blending sequences.
(PREV_POOL)	Required - pool elevation at the beginning of the previous solution time step; used with the date/pool elevation/release table and to test for initiation of new blending sequences.
(TARGET)	Required - release value extracted from the release table based on date and pool elevation.
(BLEND)	Number of time steps over which to blend table values
(BLENDTS)	Number of blending time steps over which to blend time series values into the table values
(PREV_R)	Required - Release made from the reservoir at PREV_DATE.

(NORMAL | INTERPOLATE TIME | INTERPOLATE ELEV | INTERPOLATE ALL)
Specifies how releases are determined when POOL and / or CURR_DATE values fall between points explicitly defined in the release table.

Time Series

(TS RELEASE)	Optional - time series containing release values

Carryover

(N)	Time step number since the current table blending sequence began.

(NTS)	Time step number since the current time series blending sequence began. This also corresponds to the time step number since the last non-missing value in the release time series.

II.4-RES-J-SETSUM JOINT RESERVOIR REGULATION OPERATION METHOD SETSUM

Description

Method SETSUM sums the discharges of reservoir method outputs defined within the SETSUM parametric input.

SETSUM allows users to model more than one method of a specific type (e.g, release or withdrawal) and sum the results. Multiple layers of SETMAX, SETMIN and SETSUM methods can be defined.

Parameters

(METHODS)	List of methods and identifiers that define the list of previously computed methods that are to be summed. Methods that may be used within SETSUM include SETMAX, SETMIN, SETRELEASE and SETWITHDRAW. Release and withdrawal methods cannot be combined in a SETSUM method.

Time Series

Not needed

Carryover

Not needed

Description

Method SETWITHDRAW prescribes a reservoir withdrawal according to a user-specified table of withdrawals (based on dates and pool elevations) or, if available, a time series of withdrawal values. Withdrawal table behavior can be modified by specifying three types of interpolation and using blending algorithms. If no time series is specified, the table withdrawal values are used exclusively. The calculated or specified withdrawal can be sent to another component in the system as part of an inflow timeseries to that component.

SETWITHDRAW prescribes a reservoir withdrawal according to the following algorithm. Use of the withdrawal table is also described below.

1. If an observed withdrawal time series exists and contains a non-missing value for the current solution time step, then the observed withdrawal is prescribed. Any variables tracking previous blending sequences wis reinitialized.

2. Otherwise an initial target withdrawal is drawn from the withdrawal table.

   The pool elevation state at the beginning of the current time step determines which column(s) of the table is (are) used.

   A. If reservoir pool is less than the smallest elevation in the withdrawal table, the column corresponding to the smallest elevation is used. This condition should be avoided by more fully defining the withdrawal table. It is recommended that withdrawals be specified for pool elevations at least as small as the minimum pool elevation for which the SETWITHDRAW method will be active–generally equal to the value of MINIMUMPOOL as defined in reservoir parameterization.

   B. If reservoir pool is greater than or equal to the largest elevation in the withdrawal table, the column corresponding to the largest elevation is used. This condition should also be avoided by expanding the withdrawal table well beyond the largest expected reservoir pool elevation.

   C. Otherwise the column corresponding to the largest elevation which is smaller than or equal to the reservoir pool will be used.

   The target value is then calculated according to the use (or absence) of the INTERPOLATE parameter.

   A. If INTERPOLATE was not defined, the target value is the withdrawal value corresponding to the date immediately prior or equal to the current time step.

B. If INTERPOLATE TIME was defined, the target value is linearly interpolated within the column using Julian hour representations for the date before and after the current time step. RES-J handles year-end wrap around appropriately, as withdrawal table dates do not include year definitions.

C. If INTERPOLATE ELEV was defined, a low-end target value is found as if no interpolation was defined. Using the withdrawal table column corresponding to the elevation just larger than the reservoir pool, a high-end target value is found in a similar fashion. The target value is then calculated by linear interpolation between the low-end and high-end values according to their respective pool elevations and the reservoir pool state.

D. If INTERPOLATE ALL was defined, a low-end target value is found as if INTERPOLATE TIME was defined. Using the withdrawal table column corresponding to the elevation just larger than the reservoir pool, a high-end target value is found in a similar fashion. The target value is then calculated by linear interpolation between the low-end and high-end values according to the associated pool elevations and the reservoir pool state.

3. If no blending parameters were defined, the prescribed withdrawal is set equal to the target value.

4. Otherwise RES-J tests to see if starting a new blend sequence is warranted. This can occur even if we are in the middle of blending (a partial or incomplete blend). For discussion purposes, let:

NBLEND	=	Number of time steps over which to blend. This is defined during SETWITHDRAW parameterization (value defined with BLEND or BLENDTS keyword).
N	=	Time step number since the current blend began. This value is reset to one at the beginning of each new blend and whenever a non-missing value is available from the input withdrawal time series.
TARGET	=	Target value determined according to discussion above.
PREV_W	=	Withdrawal prescribed at the end of last time step. This could be a non-missing value from a time series, a withdrawal determined from the withdrawal table or the last withdrawal prescribed as part of blending.
PREV_DATE	=	Date / time at the end of the previous solution time step.
CURR_DATE	=	Date / time at the end of the current solution time step.
PREV_POOL	=	Reservoir pool elevation at the beginning of

the previous solution time step.

POOL = Reservoir pool elevation at the beginning of the current solution time step.

Blending may be of two types: 1) blending across values in the withdrawal table when different columns and / or rows in the table are used at this time step as compared to the last time step (table blending) and 2) blending from a non-missing input withdrawal time series value to a value in the withdrawal table (time series blending).

A new table blending sequence may begin if BLEND is defined and:

A. CURR_DATE is equal to a date used in defining the withdrawal table and neither INTERPOLATE TIME nor INTERPOLATE ALL is set.

B. PREV_DATE and CURR_DATE straddle a date used in defining the withdrawal table and neither INTERPOLATE TIME nor INTERPOLATE ALL is set.

C. The column in the withdrawal table corresponding to the largest elevation which is smaller than or equal to PREV_POOL is different from the respective column for POOL and neither INTERPOLATE ELEV nor INTERPOLATE ALL is set.

Table blending is intended to smooth the transition from one table-prescribed withdrawal to another. Therefore, use of 'INTERPOLATE' may nullify 'BLEND' functionality. For example, if a change in pool elevation causes a different column to be used from one time step to the next, blending should occur. If however, 'INTERPOLATE ELEV' or 'INTERPOLATE ALL' has been defined, blending would be nullified as the transition across the elevation point would have already been smoothed by interpolation.

A new time series blending sequence may begin if BLENDTS is defined and:

A. A non-missing value exists in the withdrawal time series for PREV_DATE but the time series value is missing for CURR_DATE.

B. The time series blend is incomplete (N as initialized by a time series blend is less than or equal to NBLEND as based on BLENDTS value) and any of the new table blend conditions A, B or C, as described above, occur.

Note that if the time series continues to miss values beyond what is required to complete the time series blend (N > NBLEND), time series blending is suspended until a non-missing value is found in the input withdrawal time series. Any other blending which might be necessary will be performed under the rules and parameters of table blending.

5. If a blending sequence is active then,

   WITHDRAWAL = PREV_W + (TARGET - PREV_W) / (NBLEND - N + 1)

6. Otherwise the prescribed withdrawal is the target value.

<u>Parameters</u>

(CURR_DATE)	Required - date / time at the end of the current solution time step; used with the date/pool elevation/withdrawal table and to test for initiation of new blending sequences.
(PREV_DATE)	Required - date / time at the end of the previous solution time step; used with the date/pool elevation/withdrawal table and to test for initiation of new blending sequences.
(POOL)	Required - pool elevation at the beginning of the current solution time step; used with the date/pool elevation/withdrawal table and to test for initiation of new blending sequences.
(PREV_POOL)	Required - pool elevation at the beginning of the previous solution time step; used with the date/pool elevation/withdrawal table and to test for initiation of new blending sequences.
(TARGET)	Required - withdrawal value extracted from the release table based on date and pool elevation.
(BLEND)	Number of time steps over which to blend table values
(BLENDTS)	Number of blending time steps over which to blend time series values into the table values
(PREV_W)	Required - Withdrawal made from the reservoir at PREV_DATE.
(NORMAL | INTERPOLATE TIME | INTERPOLATE ELEV | INTERPOLATE ALL)	Specifies how releases are determined when POOL and / or CURR_DATE values fall between points explicitly defined in the release table.
(TOCOMP)	Indicates that the withdrawal shall be applied as inflow to another component, specifies which component that is and determines whether the value shall be applied this timestep or next.
(INITIALTRANSFER)	Required if TOCOMP is used - Value of last withdrawal. Used as part of carryover to ensure TOCOMP transfer mode 'NEXT'.

Time Series

(TS WITHDRAW)	Optional - time series containing withdrawal values

Carryover

(N)	Time step number since the current table blending sequence began.
(NTS)	Time step number since the current time series blending sequence began. This also corresponds to the time step number since the last non-missing value in the withdrawal time series.
(INITIALTRANSFER)	Withdrawal value calculated this timestep.

II.4-RES-J-SPILLWAY JOINT RESERVOIR REGULATION OPERATION METHOD SPILLWAY

Description

Method SPILLWAY augments a reservoir release determined by previous release methods according to the pseudo-implicit solution of the water balance including an uncontrolled spillway.

Pseudo-implicit solution is accomplished by breaking the simulation time step into a user defined number of intervals. The reservoir storage (and hence pool elevation) at the beginning of each interval determines the spill for that interval. A table matching pool elevation with spill determines the spill over the crest for the given time interval. If spill occurred during any of the intervals, SPILLWAY redefines the reservoir's pool elevation according to the state at the end of the intervals and prevents any further mass balance solution of the reservoir this time step. The reservoir's release is revised to be the sum of the release determined by previous release methods and the spill associated with the final state of the reservoir.

SPILLWAY determines whether spill occurs during the current timestep and may revise the reservoir's pool elevation and release values. For this reason, SPILLWAY should be prescribed after all release and withdrawal methods, immediately prior to any adjust method.

1. A preliminary mass balance is made over the entire timestep. If the pool elevation does not exceed the threshold of the spillway, as determined by the highest pool elevation associated with 0 spill in the table, either at the beginning or ending of the timestep, then no spill is given and the algorithm terminates.

2. Otherwise arrays are created for inflow, release and withdrawal volumes by interpolating from the value at the start of the current timestep to the value prescribed by previous methods for the end of the current timestep. The arrays are sized and volumes are calculated from flows according to the user parameterized value of INTERVALS and TIMESTEP size. Note that the release value associated with the end of the previous timestep is reduced by the value of the spill associated with the end of the previous timestep prior to initialization of the array. Arrays are also created for storage and spill. The first value in these two arrays are defined from the previous timestep. The remaining values in the spill array are initialized to 0.

3. Using each value in the arrays to represent values associated with a sub-timestep period of time, the mass balance is calculated for each sub-timestep according to the following mass balance:

$$S_{ti} = S_{ti-1} + (VI_{ti-1} + VI_{ti}) / 2 - (VR_{ti-1} + VR_{ti}) / 2 -$$

$(VW_{ti-1} + VW_{ti}) / 2 - VS_{ti-1}$

where ti is the end of the current sub-timestep
ti-1 is the end of the previous sub-timestep
S is storage
VI is inflow volume
VR is release (outflow) volume
VW is withdrawal volume
VS is spill volume

4. If S_{ti} is above the storage value associated with the minimum pool elevation for spill, the value VS_{ti} is determined from interpolation on the user parameterized spillway table.

5. Otherwise VS_{ti} is not reset from its initialized value of 0.

6. Steps 3 through 5 repeat through all sub-timesteps.

7. The end of timestep release on the owning reservoir is revised:

$$QR_T = QR_{T0} + VS_{tN} / t_{sec}$$

where QR_T is the end of timestep release
QR_{T0} is the end of timestep release determined by previous release methods
$_{VstN}$ is the volume spilled at the end of the last sub-timestep
t_{sec} is the time of a sub-timestep, in seconds, used to convert the spill volume back to a flow rate

8. The end of timestep pool elevation is revised for the owning reservoir using its elevation / storage curve.

9. A flag is set on the owning reservoir which will prevent normal solution of the mass balance as part of its solution finalization at the end of the timestep. This will preserve the ending pool determined in item 8 above.

Parameters

(CURR_DATE)	Required - date / time at the end of the current solution time step; used to reference inflow timeseries value.
(INFLOW)	Required - total inflow over the current solution time step.
(PREV_INFLOW)	Required - total inflow over the previous solution time step
(RELEASE)	Required - release prescribed by previous release methods for the end of the current solution time step.

(PREV_RELEASE)	Required - total release from the reservoir at the end of the previous time step. May contain spill if spill was non-zero at the end of the previous solution time step.
(WITHDRAWAL)	Required - withdrawal prescribed by the previous withdrawal methods for the end of the current solution time step.
(PREV_WITHDRAWAL)	Required - withdrawal prescribed for the end of the previous solution time step.
(PREV_STORAGE)	Required - storage in the owning reservoir at the end of the previous solution time step.
(PREV_POOL)	Required - pool elevation of the owning reservoir at the beginning of the previous solution time step.
(INTERVALS)	Required - number of intervals the simulation time step should be sub-divided into to enable pseudo-implicit solution of the water balance, including the spill term.
(INITIALSPILL)	Required if TOCOMP is used - Value of last withdrawal. Used as part of carryover to ensure TOCOMP transfer mode 'NEXT'.

<u>Time Series</u>

NONE

<u>Carryover</u>

(INITIALSPILL)	Spill associated with this timestep, used to determine 'pure' release at the beginning of the next timestep.